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THE OPTICAL GRAVITATIONAL LENSING EXPERIMENT. THE CATALOG OF PERIODIC VARIABLE STARS IN THE GALACTIC BULGE. II. PERIODIC VARIABLES IN FOUR BAADE'S WINDOW FIELDS: BW1, BW2, BW3 and BW4*

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ABSTRACT

We present the second part of the OGLE Catalog of Periodic Variable Stars in the Galactic bulge. 800 variable stars found in four Baade's Window fields BW1, BW2, BW3 and BW4 are presented. Among them 71 are classified as pulsating, 465 as eclipsing and 264 as miscellaneous type. The Catalog and individual observations are available in digital form from the OGLE Internet archive.

Subject headings:

*Based on observations obtained at the Las Campanas Observatory of the Carnegie Institution of Washington

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1. INTRODUCTION

The Optical Gravitational Lensing Experiment (OGLE) is a long term observing project with the main goal of probing dark matter in our Galaxy with microlensing phenomena (Paczyński 1986). After three seasons of observations toward the Galactic bulge 12 microlensing events have been detected (Udalski *et al.* 1993, 1994b, 1994c).

The huge amount of photometric measurements of a few million stars collected during the OGLE experiment is an unique material for studying the stellar variability. Large number of detected variable stars, in some cases significantly exceeding the number of all known variables of a given type, should considerably contribute to our knowledge about origin and evolution of different classes of variable stars and about structure and evolution of our Galaxy.

The search for periodic variable stars in the OGLE photometric databases has already been performed and the first part of the OGLE Catalog of Periodic Variable Stars in the Galactic bulge has been published (Udalski *et al.* 1994d; hereafter Paper I). First part of the Catalog included 213 periodic variable stars from the center of the Baade's Window field designated as BWC. This paper is a continuation of the Catalog – variable stars from four next fields: BW1, BW2, BW3 and BW4 (Udalski *et al.* 1994a) are presented in a similar form as in the first part of the Catalog.

2. The CATALOG

The photometric data presented here were collected during three observing seasons of the OGLE microlensing search starting from April 13, 1992 through September 16, 1994. Full logs of observations can be found in Udalski *et al.* (1992, 1994a, 1995). Observations were made at the Las Campanas Observatory, Chile which is operated by the Carnegie Institution of Washington. The 1-m Swope telescope equipped with 2048×2048 Ford/Loral CCD detector was used. Details of data pipeline, reduction technique and period search technique can be found in Paper I.

Present edition of the Catalog contains periodic variable stars with $\langle I \rangle$ brighter than 18 mag. In the following updates the Catalog will be extended toward fainter stars. There is also a lower limit of magnitude: $I \approx 14$ – resulting from saturation of stellar images on CCD frames. The period search was limited to periods within 0.1 – 100 days range.

The second part of the Catalog presents variable stars from four Baade's Window fields: BW1, BW2, BW3 and BW4. Each field covers approximately $15' \times 15'$ on the sky. Equatorial and galactic coordinates of these fields are given in Table 1. Each of BW1 – BW4 fields overlaps slightly (about $1' \times 1'$) with the central BWC field. The variable stars discovered in the overlapping areas during the BWC field search (Paper I) are not presented here to avoid ambiguity. In total 17236, 12681, 10779 and 13345 suspected for variability stars were searched for periodic light variations in fields BW1, BW2, BW3 and BW4, respectively.

The structure of the Catalog is identical as in the first part (Paper I). Detected variable stars from each field are grouped into three categories: pulsating stars, eclipsing stars and miscellaneous type variables. The latter category consists of stars which cannot be classified unambiguously as pulsating or eclipsing stars. It contains mostly late type, chromospherically active stars, and likely some ellipsoidal variables.

For every field and group of stars the Catalog consists of a Table with basic parameters for every periodic variable object and an atlas containing the phased light curves and 30" × 30" finding charts – part of the I-band frames. North is up and East is to the left.

The basic parameters for every object include star designation, right ascention and declination (J2000), period in days and heliocentric Julian Date of maximum light (minimum for eclipsing variables), I magnitude at maximum brightness, $V-I$ color at maximum brightness, I-band amplitude, classification and eventual remarks.

Designation of the object follows the scheme from Paper I: OGLE *field* V*number*, *eg.* OGLE BW2 V22. The variable stars in every field are initially sorted according to magnitude. Thus lower number means brighter star.

The equatorial coordinates of variable stars were calculated using transformation derived from position of stars from the HST Guide Star Catalog (Lasker *et al.* 1988). Typically about 20 GSC stars were identified in each field. Accuracy of coordinates is about 1".

Because of strategy adopted in the microlensing search, the vast majority of measurements was made in the I-band (typically 100 – 190 observations). Only about 10 V-band measurements were collected for each field. Thus, the $V-I$ color at maximum light is accurate to 0.05 mag. In some cases the color is not given – it could not be derived because either V-band coverage around maximum was not good enough or the star could not be identified in the V-band database.

Classification within pulsating and eclipsing star groups follows the scheme of the

General Catalog of Variable Stars (Kholopov *et al.* 1985).

3. Catalog of Periodic Variable Stars of the BW1, BW2, BW3 and BW4 Fields

Tables 2 – 13 and Appendices A – L contain the catalog of pulsating, eclipsing and miscellaneous periodic stars in BW1, BW2, BW3 and BW4 fields.

71 variable stars were classified as pulsating. Most of them are RR Lyr stars type ab and c. Remaining 18 objects are short period δ Scuti type pulsating stars. The periods of majority of them fall below the lower limit (0.1 day) of period search, but these stars were identified with $2 \times P$ period. Thus they probably do not represent complete sample of this type of stars in the Baade's Window. Some of RR Lyr type stars in the Baade's Window were studied by Blanco (1984). Out of 22 objects from Blanco list located in fields BW1 – 4, 18 were identified in the Catalog as pulsating stars. Two more objects previously classified as RRc type by Blanco are classified as W UMa-type eclipsing variables. Two remaining objects are missing due to reduction technique drawbacks (see Paper I). Cross-identification is given in "Remarks" column of appropriate Tables.

465 eclipsing stars were identified in BW1 – BW4 fields. The vast majority (347) of eclipsing objects belongs to W UMa type (EW). Also 94 Algol-type (EA) and 10 β Lyr-type (EB) stars were identified. 14 objects were classified as eclipsing (E) only in ambiguous cases. Amplitude of some Algol-type eclipsing stars is a lower limit because the bottom of the eclipse has not been covered. Also the periods of some Algol variables can be twice of that listed in the Table.

The miscellaneous group of stars contains 264 objects from BW1 – BW4 fields. Most of them are red giants and subgiants, probably chromospherically active stars. Some objects in miscellaneous group of variable stars might be ellipsoidal variables what is indicated in the "Remarks" column. In such a case the period should be twice of that given in the Table.

It should be noted that there is a small group of 3 very red ($V - I > 5$) stars within the miscellaneous group (OGLE BW3 V1, OGLE BW3 V2, OGLE BW4 V1). These objects have periods longer than 60 days and I amplitude about 0.3 – 1 mag. One of these stars – OGLE BW4 V1 – has the period longer than the upper limit of the period search, and was detected with shorter period. However it should be noted that its period is quite uncertain. The group is highly incomplete because the stars are bright, close to the saturation level of

the detector, and have long periods. Nevertheless it distinguishes clearly from other stars of miscellaneous group.

4. Summary

We present the second part of the OGLE Catalog of Periodic Variable Stars in the Galactic Bulge – periodic variable stars from BW1, BW2, BW3 and BW4 Baade's Window fields. 800 periodic stars with $\langle I \rangle$ brighter than 18 mag. were detected: 71 pulsating, 465 eclipsing and 264 miscellaneous type stars.

The Catalog is supposed to be an open publication and regular updates are expected when more data become available and search for variables in fainter objects will be completed. Some errors, unavoidable in this first release of the Catalog, will also be corrected. Therefore we expect a feedback from astronomical community when any errors, misclassifications etc. are found.

The Catalog and all individual observations of cataloged variable stars (JD hel., I magnitude, error) are available to astronomical community from the OGLE Internet archive using anonymous ftp service from sirius.astrouw.edu.pl host (148.81.8.1), directory */ogle/var_catalog*. See README file in this directory.

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